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# Control of Phytophthora Disease of Fruit Tree Seedlings by Neutralized Phosphorous Acid[1]

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## Abstract

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A greenhouse study was conducted to determine effects of neutralized phosphorous acid solution (NPA) on control of Phytophthora diseases of kumquat (*Fortunella margarita*) grafted on Rangpur lemon (*Citrus limon*), loquat (*Eriobotrya japonica* cv. 'Mogi') and avocado (*Persea americana* cv. 'Tainan'). The NPA solution was prepared by dissolving phosphorous acid in water and then adding equal weight of potassium hydroxide to the solution. For kumquat, 1-year-old seedlings were sprayed with NPA solution (1000 mg/L), 50 mL/seedling, for 2 or 3 times at weekly interval and then sprayed with zoospore suspensions of *Phytophthora citrophthora*, 10 mL/seedling, at 7 days after last NPA spray. After inoculation for 14 days, each seedling was recorded for disease incidence on leaves. In another experiment, 5-year-old kumquat plants grafted on Rangpur lemon were sprayed with NPA (1000 mg/L), 500 mL/plant, for 3 times at weekly interval and inoculated with the pathogen, 200 mL/plant, at 7 days after last NPA spray. For loquat, 6-month-old seedlings were treated with NPA (2000 mg/L) by soil drenching or with NPA (1000 mg/L) by spraying for 3 times at 30-day interval. The seedlings were then inoculated with *Phytophthora nicotianae* by placing one gram of pathogen-colonized wheat-oat grains on the wounded area of basal stems. For avocadoes, 6-month-old seedlings were inoculated with *Phytophthora cinnamomi* by drenching with 100 mL of chlamydospore suspension on each plant and then treated with NPA (1000 or 2000 mg/L) by soil drenching for 3 times at 3-month interval. Results showed that spraying kumquat seedlings with NPA at 1000 mg/L (a.i.) for 2–3 times significantly reduced seedling blight (< 2% infected leaves) caused by *P. citrophthora*, compared to untreated controls (> 44.8% infected leaves). Similarly, NPA sprayed three times on 5-year-old kumquat plants was also effective in reducing incidence of Phytophthora fruit rot, leaf blight and twig blight. Application of NPA at 2000 mg/L by soil drenching or at 1000 mg/L by spraying completely controlled basal stem rot of loquat caused by *P. nicotianae,* whereas more than 60% of seedlings were killed in the controls. The avocado seedlings treated with NPA by soil drenching and inoculated with the pathogen were all survived during the test period, whereas 50–60% seedlings were killed in the pathogen-inoculated control. Avocado seedlings treated with NPA were taller and heavier than the pathogen-inoculated control, but they were shorter and lighter than the non-inoculated control. This study reveals that NPA is a chemical with potential for practical use in the management of Phytophthora diseases of kumquat, loquat and avocado.

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**Key words:** Phosphorous acid, Phytophthora diseases, *P. cinnamomi, P. citrophthora, P. nicotianae,* Disease control, Kumquat, Avocado, Loquat.

## Introduction

Phosphorous acid ($H_3PO_3$) is an inorganic P fertilizer beneficial to subsequent crops (MacIntire *et al.*1950). It has also been used since 1980s to control diseases of field crops caused by oomycetes (Cohen & Coffey 1986) and other pathogens. Examples of commercial products containing neutralized phosphorous acid are Foli-R-Fos 400 (20% phosphorous acid, U. I. M. Agrochemicals, Australia) (Wicks *et al.* 1991), Nutri-Phite P Foliar (4% N-30% $P_2O_5$-8% $K_2O$, Biagro Western Sales, Inc., Visalia, CA) (Forster *et al.* 1998), Guard P. K. (7% N-21% $P_2O_5$-21% $K_2O$, Agrichem, Australia), Akomon-40 (Chaluvaraju *et al.* 2004), and Potphos (Chaluvaraju *et al.* 2004). In Taiwan, a neutralized phosphorous acid (NPA) at pH 6.2–6.7 was developed and used for control Phytophthora diseases in horticultural crops (Ann *et al.* 1997b, 2009). The NPA solution was prepared by dissolving phosphorous acid in water and then adding equal amount of potassium hydroxide to the solution.

The NPA solution is easy to prepare and is effective in the control of late blight of potato and tomato caused by *Phytophthora infestans* (Montagne) de Bary (Tsai *et al.* 2009), blight of lily caused by *P. nicotianae* Breda de Haan = *P. parasitica* Dastur (Ann *et al.* 2009), and basal stem rot of pepper caused by *P. capsici* Leonian (Ann *et al.* 2009). The objective of this greenhouse study was to determine effects of NPA in the control of Phytophthora diseases of three fruit trees, including Phytophthora blight of kumquat (*Fortunella japonica*) caused by *Phytophthora citrophthora* (Smith & Smith) Leonian (Ann *et al.* 1997b), basal stem rot of loquat (*Eriobotrya japonica*) caused by *P. nicotianae* (Chern *et al.* 1998), and root rot of avocado (*Persea americana*) caused by *Phytophthora cinnamomi* Rands (Ann *et al.* 2005).

## Materials and Methods

### Preparation of neutralized phosphorous solution (NPA)

High purity phosphorous acid ($H_3PO_3$, 99% white crystal, Aldrich Co., USA) and experimental grade potassium hydroxide (> 85% KOH pellet GR, Merck Co., USA) were used to prepare neutralized phosphorous acid (NPA) solutions at concentrations of 1000, 2000 and 5000 mg/L by the method of Ann *et al.* (2009). The procedure consists of dissolving phosphorous acid into distilled water and then adding an equal amount (1 : 1 ratio, w/w) of potassium hydroxide to the phosphorous acid solution. Ann *et al*. (2009) reported that pH values of NPA solutions at 500–5000 mg/L were 6.26–6.45.

### Pathogens and inoculum preparation

**Pathogens:** Three isolates of *Phytophthora* species were used in the study, including isolate Tari95004 ($A^1$ mating type) of *P. citrophthora* from a diseased stem of kumquat, isolate Tari95024 ($A^2$ mating type) of *P. nicotianae* from a diseased basal stem of loquat, and isolate Tari94006 ($A^2$ mating type) of *P. cinnamomi* from a diseased root of avocado (Table 1). These isolates were single-zoospore cultures, previously isolated by the senior author from host plants grown in Taiwan.

**Inoculum preparation**: The three isolates of *Phytophthora* were inoculated on VA-medium containing 5% V-8 juice (Campbell Co., USA), 0.02% $CaCO_3$ and 1.5% agar (Hwei shen Co., Taiwan), incubated at 24℃ for 3–5 days and used in this study. For inoculation of kumquat plants, a large amount of sporangia of *P. citrophthora* was prepared by the method of Hwang *et al.* (1976). Mycelial mats with sporangia were chilled at 15℃ for 4–6 hours for differentiation and release of zoospores. Zoospore suspensions were adjusted to the concentrations of about 5,000–10,000 zoospores/mL and stored in an icebox until used for inoculation. To prepare inoculum for inoculation of avocado, mycelial mates and large amount of chlamydospores were collected from five plates (9 cm diam.) of *P. cinnamomi* cultures by the method described by Hwang & Ko (1978), placed in 200 mL of distilled water, homogenized in an Onmi mixer homogenizer at 4500 rpm for 1 min and then filtered through a double-layer cheesecloth. The chlamydospore suspension was adjusted to 100–200 spores per milliliter using sterile distilled water and used for inoculation of avocado. To prepare inoculum for inoculation of loquat, five agar discs (5 mm × 5 mm × 3 mm) containing fresh mycelia mates of *P.*

**Table 1.** List of *Phytophthora* isolates used in the study

| *Phytophthora* species | Isolate No. | Mating type | Source | Location | Year of Isolation |
|---|---|---|---|---|---|
| *P. citrophthora* | Tari95004 | $A^1$ | Kumquat stem | Ilan | 1995 |
| *P. nicotianae* | Tari95024 | $A^2$ | Loquat basal stem | Taichung | 1995 |
| *P. cinnamomi* | Tari94006 | $A^2$ | Avocado root | Chiayi | 1994 |

*nicotianae* grown on VA-medium were removed and inoculated on wheat-oat grain substrate (wheat : oat : distilled water at 1 : 1 : 1 ratio; v/v/v) in each 300 mL flask containing 50 g of grain substrate. The cultures in flasks were incubated at 25℃ for one month.

### Control of Phytophthora blight of kumquat by NPA

Both young seedlings and 5-year-old plants of kumquat grafted on Rangpur lemon (*Citrus limon*) were used to study control of Phytophthora blight by NPA. For the seedling study, 1-year-old kumquat seedlings (20–30 cm in height) were planted in the growth substrate containing paddy field soil (clay loam, pH 5.5), vermiculate (no.4), perlite, and peat moss at 5 : 2 : 2 : 1 ratio (by volume) in black plastic containers (8 cm × 8 cm × 20 cm; L × W × H). The kumquat seedlings were individually sprayed with 50 mL (enough amout for covering one seedling) of NPA at 1000 mg/L at weekly interval for two or three 3 times during the winter-spring seasons (about 15–20℃). The control seedlings were sprayed weekly with distilled water, 50 mL/seeding. Both treated and control seedlings were individually inoculated by spraying 10 mL of zoospore suspension of *P. citrophthora* on each plant at 7 days after last spray of NPA. For the control without the pathogen, seedlings were sprayed with distilled water. Clear plastic bags were used to cover individual seedlings (inoculated and control) for 2 days to maintain high humidity and then removed. Disease severity was recorded at 1 and 2 weeks after inoculation by examining each seedling for lesions on leaves and gummosis on twigs. Each treatment consisted of 5 seedlings and the experiment was repeated once.

To test the effect of NPA on protection of fruit and other aboveground tissues, 5-year-old kumquat plants (about 150 cm in height × 100 cm in diam.) were grown in the growth substrate in plastic pots (36 cm in diam. × 50 cm in height), 1 plant/pot, and kept in the greenhouse. The growth substrate for the 5-year-old kumquat plants was prepared by the same method described in the seedling tests. During the winter and spring period, plants with mature green fruits were individually sprayed with 500 mL of 1000 mg/L NPA, two or three times at weekly interval. Plants sprayed with 80% fosetyl-aluminum WP (CiBaGi Co., USA) diluted 200 times (conc. ai 4000 mg/L) were used as the fungicide control. At 1 week after the last chemical application, the NPA treated plants in the greenhouse were covered with a plastic sheet and inoculated with *P. citrophthora* by spraying 200 mL of the zoospore suspension on each plant. The inoculated kumquat plants were then kept under cool conditions (15–20℃). Plants were examined for number of infected fruits and leaves at 7 days after inoculation and number of infected twigs at 21 days after inoculation. Each treatment consisted of 5 seedlings and the experiment was repeated once.

### Control of Phytophthora foot rot of loquat seedlings by NPA

Loquat seedlings cv. 'Mogi' were planted in black plastic containers (8 cm × 8 cm × 20 cm, L × W × H), containing the same growth substrate described in the kumquat study. After growing for 6 months in the greenhouse, each seedling was treated with NPA for 3 times at monthly interval by pouring 50 mL of NPA at 2000 mg/L into the drench of the growth substrate or spraying 10 mL of NPA at 1000 mg/L over the entire plant at each time. Plants treated with distilled water by drenching or spraying were used as controls. At 10 days after the second NPA application, the basal stem of each seedling was slightly wounded by knife scraping, inoculated with *P. nicotianae* by placing one gram of wheat-oat grain mixture colonized by the pathogen on the wound and rapped the inoculated stem with two layers of parafilm "M" membranes (Pechinery Co., USA). Two places were inoculated on each seedling. Plants with stems inoculated with autoclave wheat-oat grain mixture without the pathogen were used as controls. Seedlings were examined weekly and plants killed by the pathogen were recorded for a period of 3 months. Each treatment contained 10 seedlings and the experiment was repeated once.

### Control of Phytophthora root rot of avocado seedlings by NPA

Avocado seedlings of a local variety from Tainan county were planted in plastic containers (20 cm in diam. × 30 cm in height) containing soils collected from a paddy field in Chiayi county, Taiwan. The soil, belonging to clay loam with pH 5.5, was heated at 80℃ for 30 min and stored at room temperature (24–28℃) for one month before use. There were five treatments for this experiment: 1000 mg/L NPA + pathogen, 2000 mg/L NPA + pathogen, 80% fosetyl-aluminum WP (4000 mg/L) + pathogen, pathogen-inoculated control and uninoculated control. Each of the 6-month-old seedlings was inoculated with *P. cinnamomi* by pouring 100 mL of chlamydospore suspension onto the soil surface in the evening. In the next morning, 200 mL of the chemical solution (NPA or Fosetyl-aluminum) were applied to the soil surface of each plant and two more applications thereafter at 3-month interval. Plants, treated or controls, were kept in the greenhouse for three months and then recorded number of seedlings killed by *P. cinnamomi*. At the end of the experiment, all survived plants were removed and measured for plant height and total plant weight. Each treatment consisted of 10 plants and the experiment was repeated once.

### Statistical analysis

Data collected from each experiment were analyzed by analysis of variance (ANOVA), and means were compared by least significant difference (LSD) test at $P = 0.05$.

## Results

### Control of Phytophthora disease of kumquat by NPA

Results of artificial inoculation tests in the greenhouse showed that kumquat seedlings sprayed with 50 mL of NPA at 1000 mg/L for two to three times effectively controlled leaf blight and twig gummosis caused by *P. citrophthora*. The leaf infection rates of NPA treatments were 2% and 0%, respectively, for the 1st and 2nd tests, compared to 44.8% and 50.8%, respectively, for the controls (Table 2). All the infected seedlings developed symptoms of gummosis and dieback on infected twigs and they were killed within 6 months. Results also showed that application of 1000 mg/L NPA or 4000 mg/L fosetyl-aluminum on 5-year-old plants of kumquat by spraying for two to three times effectively reduced Phytophthora fruit rot of kumquat (Table 3). In the 2nd test, three applications of NPA at weekly interval completely suppressed development of Phytophthora disease on plants, whereas the disease rates on plants inoculated with *P. citrophthora* without NPA sprays were 80, 59, and 20% on fruits, leaves and twigs, respectively.

**Table 2.** Control of Phytophthora blight of kumquat seedlings by neutralized phosphorous acid solution (NPA) [z]

| Treatment [y] | No. NPA application | % Infected leaves [x] | | Other symptoms |
|---|---|---|---|---|
| | | 7 dpi | 14 dpi | |
| Test 1 | | | | |
| NPA, 50 mL/plant at 1000 mg/L | 2 | 2 b [w] | 2 b | |
| Control-1 (with pathogen) | 0 | 30.5 a | 44.8 a | Gummosis and dieback |
| Control-2 (without pathogen) | 0 | 0 b | 0 b | |
| Test 2 | | | | |
| NPA, 50 mL/plant at 1000 mg/L | 3 | 0 b | 0 b | |
| Control-1 (with pathogen) | 0 | 25.1 a | 50.8 a | Gummosis and dieback |
| Control-2 (without pathogen) | 0 | 0 a | 0 a | |

[z] Neutralized phosphorous acid solution (NPA) was prepared by dissolving phosphorous acid in distilled water and then adding equal weight of potassium hydroxide.
[y] 1-year-old seedlings of kumquat grafted on Rangpur lemon were individually sprayed with 50 mL NPA at 1000 mg/L for 2 times at weekly interval. Seedlings in the controls were sprayed with distilled water.
[x] Inoculation was done by spraying 10 mL of zoospore suspension of *Phytophthora citrophthora* on young shoots of each kumquat seedling at 7 days after the last application of NPA. Disease was rated at 7 and 14 days after inoculation of the pathogen.
[w] Means of the same test within each column followed by the same letters were not significantly different at 5% level according to LSD test.

**Table 3.** Control of Phytophthora blight of kumquat plants by neutralized phosphorous acid solution (NPA) [z]

| Treatment [y] | Concentration (ai, mg/L) | No. application | Disease incidence (%) [x, w] | | |
|---|---|---|---|---|---|
| | | | Fruit | Leaves | Twigs |
| Test 1 | | | | | |
| NPA, 500 mL/plant | 1000 | 2 | 0 b [v] | 8.1 b | 10 b |
| 80% Fosetyl-aluminum WP, 500 mL/plant | 4000 | 2 | 0 b | 7.2 b | 5 bc |
| Control-1 (with pathogen) | | | 100 a | 92.5 a | 35 a |
| Control-2 (without pathogen) | | | 0 b | 0 b | 0 c |
| Test 2 | | | | | |
| NPA, 500 mL/plant | 1000 | 3 | 0 b | 0 c | 0 b |
| 80% Fosetyl-aluminum WP, 500 mL/plant | 4000 | 3 | 0 b | 8.3 b | 0 b |
| Control-1 (with pathogen) | | | 80 a | 59.0 a | 20 a |
| Control-2 (without pathogen) | | | 0 b | 0 c | 0 b |

[z] Phosphorous acid solution was neutralized with equal weights of potassium hydroxide.
[y] 5-year-old potted plants of kumquat were individually sprayed with 500 mL chemical solution two times (test 1) or three times (test 2) at weekly interval. Seedlings in the controls were sprayed with distilled water.
[x] Inoculation was performed by spraying 100 mL of zoospore suspension of *Phytophthora citrophthora* on each plant at 7 days after the treatment of NPA or Fosetyl-aluminum.
[w] Disease incidence was recorded at 7 days after inoculation for fruit rot and leaf blight and 14 days after inoculation for twig blight.
[v] Means of the same test within each column followed by the same letters were not significantly different at 5% level according to LSD test.

### Control of Phytophthora foot rot of loquat seedlings by NPA

Results of the greenhouse experiments showed that three applications of 10 mL of NPA at 1000 mg/L by foliar spray or 50 mL of NPA at 2000 mg/L by soil drenching at 30-day intervals completely suppressed the development of stem rot of loquat seedlings caused by *P. nicotianae* (Table 4). None of the NPA-treated seedlings were killed during the study period of three months, whereas the percentage of dead seedlings in the pathogen-inoculated controls was 60 and 65% for test 1 and test 2, respectively.

### Control of Phytophthora root rot of avocado seedlings by NPA

Results of the greenhouse experiments showed that both NPA and fosetyl-aluminum were effective chemicals for control of root rot of avocado seedlings caused by *P. cinnamomi* (Table 5). During the 9 months period, no dead seedlings were found in the treatment of NPA or fosetyl-aluminum, whereas 50–60% of seedlings were killed in the pathogen-inoculated controls. Results of both tests also showed that application of 2000 mg/L NPA (100 mL/plant) by soil drenching for 3 times at 3 month interval, was the most effective method for control of avocado root rot and the treatment improved seedling growth by increasing seedling height and seedling weight (Table 5). The treatment of fosetyl-aluminum (100 mL/plant, 4000 mg/L) was the second-best, followed by the treatment of 1000 mg/L NPA. All the chemical treatments (NPA and fosetyl-aluminum) also significantly ($P < 0.05$) improved seedling vigor of avocado, compared to the pathogen-inoculated controls.

## Discussion

*Phytophthora* species are important pathogens causing serious diseases on numerous crops and are distributed worldwide (Erwin & Ribeiro 1996). In Taiwan, Phytophthora diseases are common on crops due to warm and humid climates, which are favorable for propagation and dissemination of the pathogen and development of the disease (Ho *et al.* 1995). Synthetic fungicides are generally used by growers to control crop diseases including Phytophthora diseases. In order to reduce the negative impact of synthetic fungicides, the search for materials that are effective, safe, cheap and easy to use for the control of Phytophthora diseases has become a major pursue for researchers in Taiwan.

Many reports suggest that phosphorous acid and its salts are effective and useful inorganic chemicals for control of crop diseases caused by *Phytophthora* spp. and other oomycetes (Cohen & Coffey1986; Guest & Grant 1991). Saindrenan & Guest (1995) reported that the major mechanism for control of diseases by these chemicals was due to induced host resistance to the pathogen by the phosphorous acid ion. Several products containing phosphorous compounds have been developed and used commercially for control of crop diseases caused by oomycetes (Wicks *et al.*1991; Forster *et al.*1998; Chaluvaraju *et al.* 2004). However, none of these commercial products are commonly used in Taiwan due to high price and other reasons such as easy oxidation in air. The NPA solution reported by Ann *et al.* (1997a, 2009) is cheap and easy to prepare and it is effective in the control of diseases of vegetable crops, including foliar and blossom blight of lily caused by *P. nicotianae* (Ann *et al.* 2009), basal stem

Table 4. Control of Phytophthora foot rot of loquat seedlings by neutralized phosphorous acid solution (NPA) [z]

| Treatment | Application method | Seedling killed (%) [y, x] |
|---|---|---|
| Test 1 | | |
| NPA at 2000 mg/L | Soil drench, 50 mL/plant, 3 applications at 30-day interval | 0 b [w] |
| Control-1 (with pathogen) | | 60 a |
| Control-2 (without pathogen) | | 0 b |
| Test 2 | | |
| NPA at 1000 mg/L | Foliar spray, 10 mL/plant, 3 applications at 30-day interval | 0 b |
| Control-1 (with pathogen) | | 65 a |
| Control-2 (without pathogen) | | 0 b |

[z] Phosphorous acid was neutralized with equal weights of potassium hydroxide in distilled water.
[y] 6-mo-old potted seedlings of loquat were individually inoculated with *Phytophthora nicotianae* at 10 days after the second application of NPA. Inoculation was performed by placing one gram of pathogen-colonized wheat-oat grains on each of the two wounded areas of basal stem of each seedling.
[x] Diseased plants were assessed at 90 days after inoculation.
[w] Means of the same test followed by the same letters were not significantly different at 5% level according to LSD test.

**Table 5.** Control of Phytophthora root rot of avocado seedlings by neutralized phosphorous acid solution (NPA) [z]

| Treatment [y] | Concentration (mg/L) | Seedling [x] killed (%) | Plant vigor [x] | |
|---|---|---|---|---|
| | | | Height (cm) | Weight (g/plant) |
| Test 1 | | | | |
| NPA, 200 mL/plant | 1000 | 0 | 98.8 b [w] | 311 c |
| NPA, 200 mL/plant | 2000 | 0 | 110.4 a | 381 b |
| 80% Fosetyl-aluminum WP, 200 mL/plant | 4000 | 0 | 106.3 ab | 366 b |
| Control-1 (with pathogen) | | 60 | 47.5 c | 99 d |
| Control-2 (without pathogen) | | 0 | 112.5 a | 497 a |
| Test 2 | | | | |
| NPA, 200 mL/plant | 1000 | 0 | 94.4 b | 360 c |
| NPA, 200 mL/plant | 2000 | 0 | 105.5 a | 476 b |
| 80% Fosetyl-aluminum WP, 200 mL/plant | 4000 | 0 | 98.2 b | 466 b |
| Control-1 (with pathogen) | | 50 | 62.8 c | 186 d |
| Control-2 (without pathogen) | | 0 | 109.6 a | 514 a |

[z] Phosphorous acid was neutralized with equal weights of potassium hydroxide in distilled water.
[y] Chlamydospore suspensions of *Phytophthora cinnamomi* were applied to the soil surface of 6-mo-old seedlings of loquat in the evening, 100 mL/seedling, followed by application of chemical solution (NPA or Fosetyl-aluminum), 200 mL/seedling, in the next morning. Two more chemical treatments (NPA or Fosetyl-aluminum) were applied by soil drenching at 3-month interval.
[x] Disease and plant vigor were determined at 90 days after the last chemical application.
[w] Means of the same test within each column followed by the same letters were not significantly different at 5% level according to LSD test.

rot of pepper caused by *P. capsici* (Ann *et al.* 2009) and late blight of potato and tomato caused by *P. infestans* (Tsai *et al.* 2009). This study further confirms the effectiveness and usefulness of NPA for control of Phytophthora diseases of fruit tree seedlings such as kamquat, loquat and avocado grown in the greenhouse.

Previous reports indicated that 2–3 foliar sprays of NPA at the concentration of 1000 mg/L at weekly interval prior to the inoculation of Phytophthora pathogen was effective for control of foliar and blossom blight of lily (Ann *et al.* 2009) and late blight of potato and tomato (Tsai *et al.* 2009). This study reveals that the NPA concentration and application method used in lily (Ann *et al.* 2009) as well as potato and tomato (Tsai *et al.* 2009) is also effective in the control of leaf and twig blights (Table 2) and fruit rot (Table 3) of kumquat caused by *P. citrophthora*. Meanwhile, the treatment of NPA at 1000 mg/L was equal to or slightly better than the treatment of Fosetyl-aluminum at 4000 mg/L (the recommended concentration). Ann *et al.* (2009) reported that NPA applied by soil drenching at a higher concentration (2000–5000 mg/L) was more effective than NPA applied by foliar spray at a lower concentration (1000 mg/L) in the control of Phytophthora basal stem rot of pepper. This study showed that NPA completely suppressed basal stem rot of loquat seedlings caused by *P. nicotianae,* either by soil drenching (50 mL/pot at 2000 mg/L) or by foliar spray (10 mL/plant at 1000 mg/L) was used (Table 4). The concentrations of NPA applied to loquat were relatively lower than those applied to pepper (Ann *et al.* 2009), but the efficiency of NPA in suppression of the basal stem rot in loquat was much better than the basal stem rot in pepper. The reason for such differences between loquat and pepper remains unknown.

This study suggests that NPA is an inorganic chemical with potential for management of crop diseases caused by *Phytophthora* spp. In addition to the control of Phytophthora diseases in vegetable crops in previous reports (Ann *et al.* 1997a, 2009; Tsai *et al.* 2009) and fruit trees (kumquat, loquat and avocado) in this study, it warrants further investigations on the use of NPA for management of Phytophthora diseases in other crops.

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# 利用亞磷酸中和水溶液防治果樹苗木疫病 [1]

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## 摘 要

安寶貞、王姻婷、蔡志濃。2011。利用亞磷酸溶中和水液防治果樹苗木疫病。台灣農業研究 60:149–156。

本研究評估簡便調製之亞磷酸中和水溶液 (neutralized phosphorous acid solution, NPA) 對三種果樹幼苗疫病之防治效果。一年生的長實金柑 (*Fortunella margarita*)/廣東檸檬 (*Citrus limon*) 嫁接苗每株噴布 50 mL NPA (濃度 1000 mg/L)，每星期施用一次，2–3 次後，再接種 *Phytophthora citrophthora* 的游走子懸浮液，接種 14 天後疫病幾乎不會發生；而對照處理則有 44.8% 與 50.8% 的葉片染病，並且伴隨枝條流膠與枝枯。而五年生的結果金柑苗每株噴布 500 mL 相同濃度的 NPA 三次，可以完全保護果實、葉片及枝條不被病菌感染；而接種病菌的對照處理的發病率分別為 80%，59% 及 20%，發病之枝條同樣伴隨流膠與枝枯。六個月大的茂木枇杷 (*Eriobotrya japonica* cv. ‘Mogi’) 實生苗之土壤表面每株灌注 50 mL NPA (2000 mg/L) 或噴布 10 mL NPA (1000 mg/L) 三次，每次間隔 30 天，之後莖基部接種疫病菌 *P. nicotianae* 之麥粒菌種，90 天後均無幼苗死亡；而對照處理則有 60%與 65%的死亡率。六個月大的台南種酪梨 (*Persea americana* cv. ‘Tainan’) 在接種 *P. cinnamomi* 厚膜孢子懸浮液後，每盆土壤灌注 100 mL NPA (1000 mg/L 或 2000 mg/L) 三次，每次間隔 90 天，NPA 的處理在試驗期間均無植株死亡，而接菌對照處理有 50%與 60%死亡率，NPA 處理組的平均株重比接菌對照處理顯著為重，但比不接菌對照處理顯著為差。

**關鍵詞：** 亞磷酸、疫病、*Phytophthora cinnamomi*、*Phytophthora citrophthora*、*Phytophthora nicotianae*、疫病防治、金柑、枇杷、酪梨。

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